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storage of TEXAS RED GRAPEFRUIT in modified atmospheres

• *A Progress Report*

U.S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

STORAGE OF TEXAS RED GRAPEFRUIT IN MODIFIED ATMOSPHERES

--A Progress Report--

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Grapefruit is more difficult to store than other popular citrus fruits. Its delicate flavor is easily destroyed or masked by off-flavors or extraneous flavors absorbed from its surroundings.

Grapefruit develops an orange color when stored for 6 weeks or more at 50° F., becomes pitted and unsightly in a few weeks at 40°, and develops watery breakdown, pitting, and post-storage decay when stored at 33°. Moreover, "storage" on the tree beyond midseason results in a general fading of internal and external color, reduction in nutrients and flavor, and development of bitterness with sprouting of the seeds.

In tests at the Harlingen, Texas, station of the Market Quality Research Division, in which grapefruit were stored in sealed polyethylene film bags, pitting at 40° was sometimes prevented, apparently by the modification of the atmosphere within the bags resulting from the respiration of the enclosed fruit. Analyses of these atmospheres showed extreme variations from one film bag to another in the amount of increase in carbon dioxide and decrease in oxygen concentration. Inherent imperfections and nonuniform thickness of the polyethylene film bags were the major causes of the variations.[1] If the gas concentrations were adequately controlled, it might be possible to eliminate pitting and avoid other undesirable effects which often attend film bag storage.

1957-58 PRELIMINARY TESTS

In 1957, gas-tight chambers were constructed so that the enclosed gases could be sampled and their concentrations adjusted by adding air or compressed bottle gases.

A sample of 15 unwashed early-season grapefruit (picked December 2) was placed in each of four chambers and stored at 40° F. A control sample was stored in a carton in rapidly circulating air at the same temperature to simulate conventional storage. At the end of the 4 weeks' cold storage and a 1-week 70° F. holding period, no decay or off-flavors were noted in the experimental fruit. Ranges of atmospheric gas concentrations and the mean percentages of grapefruit surface area covered by pitting are shown in the following tabulation:

	CO_2	O_2	Pitting
Controlled-atmosphere storage:	*Percent*	*Percent*	*Percent*[1]
	10-15	(15-20	0.3
		(5-10	Trace
	0-5	(15-20	3.2
		(5-10	3.1
Air storage:			
	Trace	20.8	12.8

[1] One percent of surface equals area of a 1-cent piece.

[1] Hardenburg, R. E., and Anderson, R. E. Evaluation of Polyethylene Box Liners and Diphenylamine for Storage of Apples. Proc. Am. Soc. Hort. Sci. 73:57-70. 1959. Smock, R. M., and Blanpied, G. O. A Comparison of Controlled Atmosphere Storage and Film Liners for the Storage of Apples. Proc. Am. Soc. Hort. Sci. 71:36-44. 1958.

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Only minute amounts of pitting occurred in 10-15 percent carbon dioxide at either oxygen level. Where carbon dioxide levels were kept below 5 percent, a noticeable amount of pitting occurred; even so, the percentage of pitted surface was only one-fourth that of the check fruit.

A second test was made at 40° F. with washed midseason fruit (picked January 14), using samples of 36 grapefruit each in all combinations of 3 ranges of carbon dioxide and 3 ranges of oxygen concentration. A control sample was stored in a carton as before. Ranges of gas concentrations are given in table 1 along with fruit condition after 9 weeks' storage at 40° plus 1 week at 70°.

TABLE 1.--Condition of samples of 36 midseason (1957-58) grapefruit stored 9 weeks at 40° F. and held 1 week at 70° F.

Storage treatment	CO_2	O_2	Pitting	Decayed grapefruit	Juice flavor
	Percent	*Percent*	*Percent*[1]	*Number*	
Fruit as harvested			---	---	Excellent
Controlled-atmosphere storage:					
	12-16	13-18	Trace	21	Good
		7-13	1.0	20	Fair
		1- 5	Trace	24	Poor
	7-11	13-18	Trace	8	Good
		7-13	Trace	5	Fair
		1-5	Trace	14	Poor
	2-6	13-18	4.0	4	Good
		7-13	0.8	3	Good
		1- 5	0.8	5	Fair
Air storage:					
	Trace	20.8	11.3	2	Good
"Tree-stored"			---	---	Excellent

[1] 1 percent of surface equals area of a 1-cent piece.

Pitting was markedly greater in check fruit than in fruit kept in controlled-atmosphere chambers. With one exception, the percentage of pitting was greater at low carbon dioxide tensions. Off-flavors were associated with low oxygen concentrations. Over 50 percent decay occurred at all three high carbon dioxide treatments; some decayed fruits were noted for all treatments, including the check carton.

It was observed that the internal color of the fruit was preserved by 40° temperatures during the storage period. Grapefruit remaining on the tree faded considerably during the period, but its flavor improved.

A third storage test using washed late-season grapefruit (picked March 26) was begun but was discontinued because of high incidence of Oospora watery soft rot. The decay may be attributed partly to the washing operation, although mature fruit is generally conceded to be more susceptible to decay.

Preliminary tests showed that increased carbon dioxide in the atmosphere surrounding the fruit reduced pitting of grapefruit stored at 40° F. Data from midseason storage suggest that decay may be associated with high carbon dioxide and that a minimum concentration of 1 percent oxygen may be too low to maintain good flavor. Storage in the 7-13 percent oxygen range resulted in good flavor only when the carbon dioxide concentration was low.

1958-59 EXPERIMENTAL STORAGE TESTS

Procedure

Ruby Red grapefruit were harvested from a commercial orchard near Los Fresnos, Tex., early in the season, November 13, and in midseason just prior to flowering time, February 9. Internal color of the fruit was poor, probably due to cultural practice or climatic conditions. Some Diplodia stem-end decay had occurred earlier in the year because of unusual moisture conditions; consequently, all but three check lots of fruit were treated with a chemical dip. [2]

At each harvest period, 27 modified-atmosphere treatments were used, consisting of all combinations of 3 temperatures, 3 concentrations of carbon dioxide, and 3 concentrations of oxygen (tables 2, 3, and 4). Lots of 30 grapefruit were weighed and placed in gas-tight, 50-liter chambers and sealed with glass lids. Atmospheres were modified by displacing the chamber air with nitrogen until the oxygen concentrations were reduced and then introducing the desired amounts of carbon dioxide. Sample lots, with and without the chemical dip, were stored in cartons in circulating air at each of the three temperatures, to simulate conventional storage conditions.

Atmospheres in the 50° F. chambers were analysed and corrected daily, in the 40° chambers every second day, and in the 33° chambers every third day. With the exception of the 33° treatments, which were erratic, variations in the gas tensions within the chambers were generally held within the ranges given. Decayed fruits were recorded and removed from the chambers periodically and the modified atmospheres re-established.

An additional sample representing tree-stored fruit was picked from the orchard at the end of the storage period to be held, along with the cold storage fruit, at 70° for 1 week. After this holding period, which corresponds to a typical storage-to-consumer marketing time, the fruit was weighed and the percentage of surface covered by rind breakdown, including pitting, aging, and red blotch, was estimated. The area of a 1-cent piece is approximately equal to 1 percent of the surface of a grapefruit (size 70 or 80). Areas of 0.2 percent or less are listed as traces and might not be noticed by the consumer. The juice was extracted and analysed for total solids with a Brix[3] hydrometer. Total acids expressed as percentage of citric acid was measured by titrating with an alkaline solution to a pH of 8.1. The juice was tasted about 30 minutes after extraction and rated as "excellent--fresh flavor," "good--acceptable to critical tastes," "fair--slight off-flavors but acceptable to most persons," and "poor--insipid or definite off-flavors and unacceptable."

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[2] November fruit, 1-minute dip, 2% sodium-o-phenylphenate (Dowicide A) plus hexamine 1 to 20 in water containing 4 grams caustic soda per liter of mixed solution (75° F.). No water rinse. February fruit, 2-minute dip, 2% sodium-o-phenylphenate plus hexamine in same proportions as above. Fruit given a momentary dip in water after chemical dip.

[3] The brix hydrometer scale expresses soluble solids directly as percent sucrose.

RESULTS

Early-Season Storage

When the storage of early-season fruit was terminated at the end of 6 weeks, no decay had developed. Appreciable rot did appear during the 70° F. holding period (table 2), particularly in those samples stored in high carbon dioxide levels at 33°. Considerably more weight loss occurred in the air-stored fruit, which reflected the lower relative humidity of the refrigerated room compared to the atmosphere in the controlled chambers.

Fruits at 50° F. were practically free of rind breakdown. Considerable pitting occurred in fruits stored at 40° in air and in those controlled at high oxygen levels. High percentages of surface breakdown at high carbon dioxide levels at both 40° and 33° were due to large dark brown scaldlike areas similar to red blotch, which may be associated with the wet season. At 33°, rind breakdown was severe in all but one controlled atmosphere.

A dull appearance was noted in many of the grapefruit stored at either 40° or 33° F. Check fruit which were not treated with the chemical dip were noticeably brighter.

Percentage of soluble solids as expressed by the Brix readings increased slightly in the check lots during storage but changed little in the treated samples, probably because fruit stored in air lost more water than those in the chambers. Total acids and pH of the juice are not shown, but remained approximately the same as in the fruit before storage, namely 1.2 percent acids and pH of 3.1.

Flavor of the juice was acceptable in all lots stored at 50° F. Off-flavors were detected in fruit stored at high carbon dioxide tensions at 40°. Poor flavor of individual fruits from 33° storage tended to be correlated with rind breakdown.

There were striking differences in external color of fruit in 50° F. controlled-atmosphere storage. Grapefruit stored at the low oxygen concentrations retained their original greenish cast, those at the intermediate oxygen tensions were yellow, while the fruit at high oxygen tensions, as well as those stored in air, had the orange cast typical of stored fruit. Colors deepened slightly during the holding period and continued to deepen thereafter. The original greenish cast was maintained by all the fruit stored at 33° and 40°. Grapefruit stored at 40° in the low oxygen, low carbon dioxide treatment held their color for several weeks after the storage period, eventually yellowing, but not becoming orange.

Internal red color of the pulp did not change perceptibly in any of the treatments during the short storage period.

Midseason Storage

To avoid the dull skin condition observed in early-season fruit after storage, the midseason grapefruit were rinsed in water after the chemical dip. Oxygen and carbon dioxide ranges were adjusted downward and closer tolerances were set (tables 3 and 4). As before, the limits of variation were difficult to maintain in the 33° F. chambers.

Late in the storage period, it became evident that the low point in the range of oxygen concentrations was too low. Whenever oxygen tensions were allowed to decrease to 2.6 percent or lower, carbon dioxide evolution increased in the days following, apparently due to a shift to anaerobic respiration. Biale[4] (1954), working with Valencia oranges, Washington navels, and lemons, reported critical oxygen concentrations of 2.5 to 5 percent above and below which respiration, as measured by carbon dioxide evolution, increased. Below the critical oxygen level, the volume of oxygen uptake was much less than that of carbon dioxide evolution--evidence of the onset of detrimental fermentative processes.

[4] Biale, J. B. Physiological Requirements of Citrus Fruits. Citrus Leaves 34(7): 6-7, 31-33. 1954. and Proc. Conference on Transportation of Perishables, Univ. Cal. Davis, April 26-28, pp. 38-45. 1954.

TABLE 2.--Average condition of 30-fruit samples of early season (1958-59) grapefruit stored 6 weeks and held 1 week at 70° F.

Storage treatment	CO_2	O_2	Weight loss	Surface breakdown[1]	Decayed fruits	External appearance and texture	Juice: Total solids	Juice: Flavor
	Percent	*Percent*	*Percent*	*Percent*	*Number*		*Percent*	
Fruit as harvested	---	---	---	---	---	Greenish-firm	8.6	Good
Air storage:								
50° dipped	Trace	20.8	2.8	0	0	Orange-slightly soft	9.4	Good
50° untreated	Trace	20.8	2.3	0	0	do.	9.5	do.
Controlled-atmosphere storage at 50°	10.5-12.5	14.5-17.5	1.0	0	1	Orange tinge-firm	8.6	Good
		8.5-11.5	1.0	0	0	Yellow-firm	8.6	do.
		2.5-5.5	0.8	Trace	0	Greenish-firm	8.6	Fair
	6.5-8.5	14.5-17.5	1.0	0	0	Orange tinge-firm	8.6	Good
		8.5-11.5	1.3	0	0	Yellow-firm	8.6	do.
		2.5-5.5	1.3	0	0	Greenish-firm	8.9	do.
	2.5-4.5	14.5-17.5	1.2	0	0	Orange tinge-firm	8.7	Good
		8.5-11.5	1.2	0	0	Yellow-firm	9.0	do.
		2.5-5.5	1.0	0	0	Greenish-firm	8.9	do.
Air storage:								
40° dipped	Trace	20.8	3.8	8	0	Very dull-greenish-firm	9.3	Good
40° untreated	Trace	20.8	1.8	10	2	Greenish-firm	9.5	do.
Controlled-atmosphere storage at 40°	10.5-12.5	14.5-17.5	0.8	55	2	Very dull-greenish-firm	8.7	Poor
		8.5-11.5	0.7	28	0	Greenish-firm	8.4	Fair
		2.5-5.5	0.7	6	0	do.	8.3	Poor
	6.5-8.5	14.5-17.5	1.2	11	1	Dull-greenish-firm	8.6	Fair
		8.5-11.5	1.0	1.2	0	Slightly dull-greenish-firm	8.5	Good
		2.5-5.5	1.0	Trace	0	do.	8.7	do.
	2.5-4.5	14.5-17.5	1.5	1.4	0	Dull-greenish-firm	8.8	Good
		8.5-11.5	0.3	0.5	0	Very dull-greenish-firm	9.0	do.
		2.5-5.5	0.3	Trace	0	Greenish-firm	8.6	do.
Air storage:								
33° dipped	Trace	20.8	2.6	3	0	Very dull-greenish-firm	9.2	Good
33° untreated	Trace	20.8	1.5	Trace	2	Greenish-firm	9.3	do.
Controlled-atmosphere storage at 33°	10.5-12.5	14.5-17.5	0.7	40	21	Very dull-greenish-firm	8.7	Poor
		8.5-11.5	0.5	39	8	do.	8.4	Fair
		2.5-5.5	1.0	22	7	do.	8.5	Poor
	6.5-8.5	14.5-17.5	0.5	21	1	Very dull-greenish-firm	8.4	Poor
		8.5-11.5	0.8	1.6	0	do.	8.6	Fair
		2.5-5.5	0.3	2	0	do.	8.7	Good
	2.5-4.5	14.5-17.5	0.5	7	0	Very dull-greenish-firm	8.5	Poor
		8.5-11.5	1.0	7	0	do.	8.9	Good
		2.5-5.5	0.8	0.8	0	Dull-greenish-firm	8.7	Poor
"Tree-stored"	---	---	---	---	---	Yellow to greenish-firm	9.2	Good

[1] Includes pitting, aging, and "red blotch." One percent of surface equals area of 1-cent piece.

TABLE 3.--Number of midseason (1958-59) grapefruit decayed from 30-fruit samples during storage plus 1 week at 70° F.

Storage treatment			Decay during storage period of:							Total of decayed grapefruit
Temperature, degrees F.[2]	CO_2	O_2	7-8 weeks	9-10 weeks	11-12 weeks	13-14 weeks	15-16 weeks	17-18 weeks	19 weeks[1]	
Air storage:	*Percent*	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
50° dipped....................	Trace	20.8	0	0	0	0	0	0	2	2
50° untreated................	Trace	20.8	0	0	0	0	0	2	2	4
Controlled-atmosphere storage at 50°	8.5-10.0	12.5-14.0	1	2	1	14	4	5	3	30
		7.5- 9.0	0	0	3	8	8	7	4	30
		2.5- 4.0	2	3	4	10	3	4	4	30
	5.5- 7.0	12.5-14.0	0	0	0	0	3	10	10	23
		7.5- 9.0	1	0	0	0	3	3	9	16
		2.5- 4.0	0	0	1	4	1	5	14	25
	2.5- 4.0	12.5-14.0	0	0	0	0	0	2	9	11
		7.5- 9.0	0	0	0	2	4	1	12	19
		2.5- 4.0	0	0	0	0	2	6	11	19
Air storage:										
40° dipped....................	Trace	20.8	0	1	1	0	1	1	14	18
40° untreated................	Trace	20.8	0	0	0	0	0	4	15	19
Controlled-atmosphere storage at 40°	8.5-10.0	12.5-14.0	0	0	0	23	4	3	0	30
		7.5- 9.0	0	1	4	6	9	7	3	30
		2.5- 4.0	0	0	3	10	7	10	0	30
	5.5- 7.0	12.5-14.0	0	0	8	8	8	4	2	30
		7.5- 9.0	0	0	0	10	0	16	4	30
		2.5- 4.0	0	0	2	0	3	11	12	28
	2.5- 4.0	12.5-14.0	0	0	4	0	14	8	4	30
		7.5- 9.0	0	3	0	9	3	9	6	30
		2.5- 4.0	0	1	0	2	0	3	9	15
Air storage:										
33° dipped....................	Trace	20.8	0	0	0	0	0	0	18	18
33° untreated................	Trace	20.8	0	0	0	0	0	2	22	24

[1] One week at 70° F. after 18-week storage.
[2] In each of the modified-atmosphere treatments stored 18 weeks at 33° F., all fruits decayed during the 1-week holding period at 70°.

TABLE 4.--Condition of midseason (1958-59) grapefruit stored 18 weeks and held 1 week at 70° F.

Storage treatment[1]			Condition after storage				Juice			
Temperature, degrees F.	CO_2	O_2	Weight loss	Surface break-down[2]	Appearance	Texture	Total solids	Total acid	pH	Flavor
	Percent	*Percent*	*Percent*	*Percent*			*Percent*	*Percent*		
Fruit as harvested..............	---	---	---	---	Greenish	Firm	9.5	1.08	3.22	Excellent
Air storage:										
50° dipped..................	Trace	20.8	6.4	0.2	Orange-yellow	Very soft	8.5	0.83	3.46	Good, slightly bland
50° untreated...............	Trace	20.8	5.9	0.2	do.	do.	8.7	0.80	3.49	do.
	5.5-7.0	7.5- 9.0	3.0	0.5	Orange-yellow	Firm	8.2	0.87	3.41	Fair
Controlled-atmosphere storage at 50°	2.5-4.0	12.5-14.0	1.6	6.3	Orange	Slightly soft	8.0	0.82	3.48	Good, slightly tart
		7.5- 9.0	2.9	1.5	Slightly orange	do.	8.2	0.89	3.40	Good, slightly bland
		2.5- 4.0	2.5	3.3	Greenish-yellow	Very firm	8.0	0.87	3.37	Excellent
Air storage:										
40° dipped..................	Trace	20.8	6.1	4.8	Greenish	Very soft	8.5	0.92	3.39	Fair
40° untreated..............	Trace	20.8	6.2	6.0	do.	do.	8.4	0.94	3.38	Good
Controlled-atmosphere storage at 40°	2.5-4.0	2.5- 4.0	1.6	0.5	Greenish	Firm	7.7	0.90	3.39	Fair
Air storage:										
33° dipped.................	Trace	20.8	0.9	17.0	Gray-green	Soft	7.7	0.86	3.45	Fair
"Tree-stored".................					Pink-white	Firm	7.8	0.64	3.59	Poor, very watery

1 Includes only treatments in which 10 or more fruits were sound at end of test.
2 Includes pitting, aging, and "red blotch."

Decay was noted in the seventh week of storage and developed extensively in the controlled-atmosphere chambers before the termination of the storage at 18 weeks (table 3). Diplodia stem-end rot was the principal decay at 50° F. and penicillium green mold prevailed at 40°. Decay did not develop until the 17th week at 33°; however, when the chambers were opened and the fruit exposed to 70°, the grapefruit became soggy and decayed completely. Some air-stored fruit at this temperature also had the grayish, glassy, frozen appearance typical of watery breakdown so prevalent in the controlled-atmosphere lots.

A relationship between carbon dioxide concentration and decay in 40° and 50° F. storage is apparent. At the high carbon dioxide concentration, there was 100 percent decay; at the intermediate carbon dioxide tensions, 152 out of 180, or 84 percent; at the low carbon dioxide tensions, 124 out of 180, or 69 percent; and in normal storage air (fruit in cartons), 43 out of 120, or 36 percent decay. The saturated atmosphere in the sealed chambers probably is partly responsible for the higher percentage of decay as compared with fruit in normal storage air at lower relative humidities. Fruit condition and the results of juice analysis are presented in table 4, covering tests in which 10 or more fruits remained undecayed at the end of 19 weeks. Weight loss of grapefruit stored in circulating air was two to three times greater than that of grapefruit stored in the moist controlled atmosphere.

Many of the grapefruit stored at 50° developed brown, sunken areas around the buttons, typical of aging. These are included in the measurement of surface area affected by rind breakdown. Pitting of other surfaces of the fruit stored at this temperature occurred chiefly where the fruit contacted the wooden racks in the chambers.

Differences in external color were similar to those of the early-season test. Low oxygen tensions at 50° F. and temperatures of 40° maintained the original greenish appearance of the grapefruit. Fruit at 50° and high oxygen tensions developed an orange cast within the first 6 weeks, then faded back toward yellow. Fruit remaining in the orchard were pinkish-white by the end of the storage period (June 30).

The internal color of the grapefruit for this experiment was unusually pale at harvest; no additional fading was apparent in either the check or controlled atmosphere lots.

DISCUSSION

The aim of storage should be to maintain the fruit as nearly as possible in its original fresh condition. These experiments have demonstrated that controlled atmospheres were effective in reducing rind breakdown and in preserving peel color and firm texture for relatively short storage periods. However, substantial decay losses occurred in controlled atmospheres during the longer (18 weeks) storage test. In both experiments, there was a tendency to greater amounts of decay at higher carbon dioxide tensions. Future investigations should be made in which carbon dioxide is kept as low as possible.

High relative humidities in the controlled-atmosphere chambers undoubtedly contributed to the higher incidence of decay. Air in motion with about 85 percent relative humidity surrounded the cartons containing the control fruit. Within the chambers there was no circulation of the atmosphere, relative humidities were high, and minor temperature changes caused moisture to condense on the fruit. A lower relative humidity might conceivably condition the peel to resist infection, and provide conditions less favorable for spore germination and the growth of decay-producing fungi.

Maintenance of harvest peel color was shown strikingly in grapefruit stored at 40° and 50° F. with low oxygen tensions. Because of the lack of good pigmentation in the red pulp of the grapefruit available for these tests, preservation of internal color by controlled-atmosphere storage could not be demonstrated. According to Lime et at.,[5]

[5] Lime, B. J., et al. Pigmentation, Pigment Analysis and Processing of Stored Grapefruit. Jour. Rio Grande Valley Hort. Soc. 13:30-38. 1959.

pigmentation of the pulp develops in the small immature fruit, reaches a maximum before the fruit reaches full size and acceptable maturity, and then gradually fades. Lycopene (the major red pigment) content in the fruit by February is less than half that present in the fruit in November. It is therefore important that further fading be prevented.

It was noted that grapefruit stored for 6 weeks at 40° F. in low carbon dioxide, low oxygen tensions held their yellow color several weeks at room temperature without becoming orange. This observation suggests the residual effect reported [6] for certain apple varieties which, after removal from controlled atmosphere, remain marketable longer than do cold-storage apples. However, the occurrence of off-flavors in grapefruit stored for a longer period indicates that these conditions are not ideal.

Conventional storage in air at 40° F. sometimes results in chilling injury (pitting) of grapefruit in about 2 weeks. Treatments which tend to dry the fruit, such as dry atmosphere and air movement, favor pitting. [7] Since check fruit was subject to dryer conditions than the fruit in controlled-atmosphere chambers, and no humidity control was established in the chambers, it is impossible to state explicitly the influence of the atmospheric gas concentrations on the incidence of pitting. Assuming, however, that relative humidities were comparable within the controlled-atmosphere chambers, then the data of the 6 weeks' storage experiment indicate that pitting becomes less severe as the concentrations of either oxygen or carbon dioxide are decreased.

Although pitting was limited to trace amounts by some treatments, it should be pointed out that even minute amounts of pitting may be significant in that the lesions may facilitate infection by decay organisms.

SUMMARY

Early and midseason Texas red grapefruit were stored at various temperatures and oxygen and carbon dioxide levels.

After 6 weeks' storage, early fruit tended to decay and develop off-flavors only at high carbon dioxide concentrations and low temperatures. At 40° F., pitting was controlled in low oxygen tensions. Treatments at low oxygen tensions maintained the green peel color at all storage temperatures. Storage at 40° and 33° F. preserved the greenish peel color in treated and check fruit.

Midseason fruit stored in controlled atmosphere decayed considerably more than air-stored fruit during 18 weeks' storage, probably because of high humidity in the chambers. High carbon dioxide concentrations also favored decay.

Fresh fruit flavor, peel color, and firmness were maintained better in some of the controlled-atmosphere treatments than in conventional air storage.

Until further study shows how decay can be reduced in controlled-atmosphere storage of grapefruit, no recommendations can be made for its use. The present studies indicate that the best temperature to prevent surface breakdown and maintain greenish color is probably between 40° and 50° F., that oxygen concentration should be about 3 percent, and that carbon dioxide should be kept as low as possible.

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[6] Kidd, F., and West, C. Recent Advances in the Work of Refrigerated Gas-Storage of Fruit. Jour. Pom. and Hort. Sci. 14:299-316. 1937. Smock, R. M., and Van Doren, A. Controlled-Atmosphere Storage of Apples. Cornell Univ. Agr. Expt. Sta. Bul. 762:1-45. 1941.

[7] Brooks, Charles, and McColloch, Lacy P. Some Storage Diseases of Grapefruit. Jour. Ag. Res. 52:319-351. 1936.